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hypernuclei and hyperons

CAPTAIN ALBERT W. HARRISON, USAF, Nuclear Physics Division (AFOSR)

Since the discovery of the first hypernucleus in 1952, a "new" field in experimental nuclear physics has developed. Very little is yet known of the character of the strong nuclear forces, that is, the forces acting between the nucleons of a nucleus and which are effective over very short distances of the order of 10^{-13} centimeters.

A hypernucleus is a nucleus in which a hyperon has substituted for one of the normal nuclear building blocks, the protons and neutrons. Hyperon is the name given to those unstable elementary particles which are heavier than protons and neutrons. The lifetime of most hyperons is of the order of one ten billionth of a second. This seems a very short time, but is adequately long on the nuclear scale to actually be experimentally observed. Hypernuclei afford one the opportunity to obtain additional information about nuclear forces by comparing the behavior and characteristics of the various hypernuclei with the behavior and characteristics of the comparable normal nuclei. Of all the hyperons now known, only the Lambda (Λ) hyperon forms hypernuclei which live long enough to be adequately observed. All other hyperons react extremely rapidly with individual neutrons or protons in the nucleus to form other products and are not observed as hypernuclei.

The creation and subsequent decay of hypernuclei are observed mainly by exposing stacks of film emulsion to accelerator beams, usually negative K meson beams, and observing and measuring the tracks left in the film. The "film stacks" are made by stacking layers of film emulsion, which are somewhat similar to the film (emulsion) used in cameras. Negative K mesons are used because they give the highest hypernuclei production rate of the various presently available particle beams.

AFOSR is presently supporting the research of one of the foremost groups in the world working in this field. This group, located at the Enrico Fermi Institute of Nuclear Studies

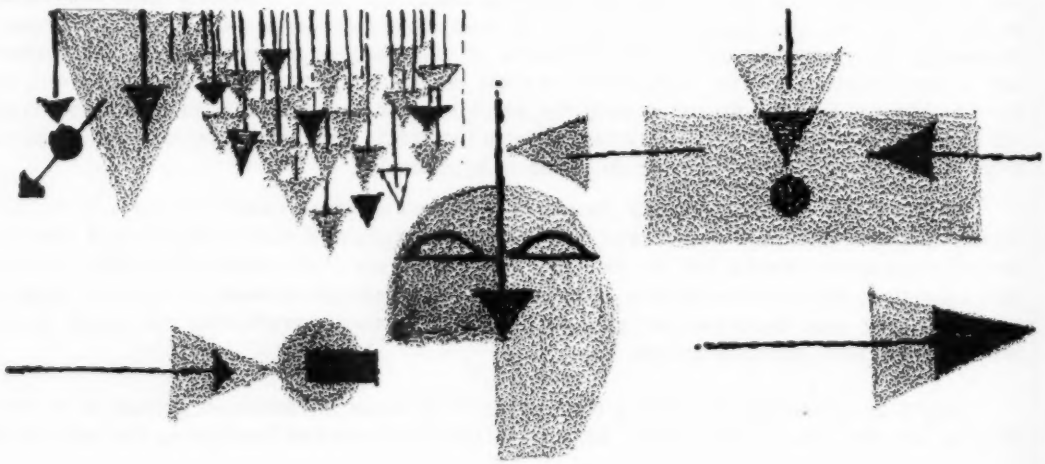
at the University of Chicago, is headed by Professor V. L. Telegdi. His collaborators at present are: Dr. G. Tomasini from the University of Genoa; Professor R. Levi Setti; Dr. D. Davis from University College, London; Mr. M. Raymund; and Mrs. N. Crayton - Karper.

Their work is made quite tedious by the requirement, necessary for complete kinematic analysis and the resulting positive identification of a given hypernucleus, that all the decay products from the hypernucleus disintegration be charged. If any of these are neutral (neutrons, π^c mesons, etc), they will not leave tracks in the emulsion. Therefore, it is not possible to determine that portion of the reaction energy carried off by these particles. The number of useable events per exposure is therefore greatly reduced since many of the possible decay modes contain neutral particles.

Recently the group has discovered several new hypernuclides: $\wedge Li^{10}$, $\wedge B^{10}$, and $\wedge B^{13}$. The subscript here means that a Lambda hyperon has been added to Li^9, B^9, B^{12}. In addition, they have analyzed new, uniquely identified, hypernuclei, $\wedge He^7$, $\wedge Li^7$, $\wedge Li^8$, $\wedge B^{11}$, and $\wedge B^{12}$. These analyses constitute the equivalent of all other hypernuclei of this type recorded in the remainder of the world.

One of the group, Professor R. Levi Setti, has recently exposed an improved type of emulsion stack at the CERN high energy accelerator. A method has recently been developed of "loading" the emulsion with an aqueous solution of lithium salts. These emulsions must be kept at dry ice temperature until used, but this has proved to be no problem. The "loading" leads to much higher concentration of lithium, hydrogen, and oxygen. This greatly increases the probability of obtaining useable events in a given exposure by providing more atoms per unit volume in the emulsion, and extends the range of observed hypernuclei to lower and higher masses. Both a large number of events and as wide a range of masses as possible are desirable for adequate theoretical interpretation.

The end result is to assist in understanding of nuclear forces, still the most potent energy source known.



skyscraper system

Optical Physics Laboratory (AFCRL)

A KC-135 aircraft has been specially instrumented under AFCRL direction to detect and analyze infrared, visible, and ultraviolet radiation from missiles during flight and reentry. The experiments to be carried out with this aircraft are designed to discover more about the characteristic optical radiations of different types of U.S. missiles.

The techniques for measuring missile radiations and the instrumented aircraft represent the culmination of several years' research by AFCRL scientists. The high altitude missile radiation measurement system, known as "Skyscraper", has been transferred to the MIT Lincoln Laboratory which will conduct flights to evaluate the system.

The Skyscraper system overcomes several limitations of ground based equipment used to obtain data on missile radiation characteristics. One such limitation is that of atmospheric attenuation. This attenuation will be markedly reduced by conducting the measurements at altitudes above 30,000 feet.

The airborne system consists of a precision tracker and a complex multiple spectrometer which analyzes optical radiations over a wide spectrum. The most interesting part of the system is a large pressure box, about the size of a broom closet, which houses the first part of the optical system. This pressure box is built into the aircraft. A panel, fitting flush with the aircraft fuselage, opens to the outside air when the system is in use and uncovers a 20 by 30 inch flat mirror. This mirror reflects any radiation incident upon

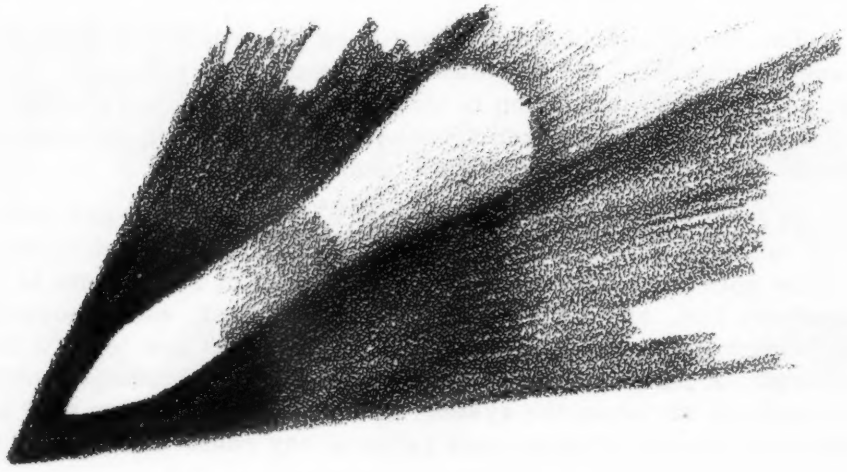
it into an optical telescope. Since temperature changes introduce expansions or contractions and thus affect the precise alignment of the optical system, forced hot air (at a carefully controlled temperature and flow rate) is introduced into this cavity.

The optical radiation from the missile, reformed by the telescope, is directed through a pressure window into a complex multiple spectrometer unit which continually samples the radiation. Data is recorded by a high speed magnetic tape system for storage and later analysis.

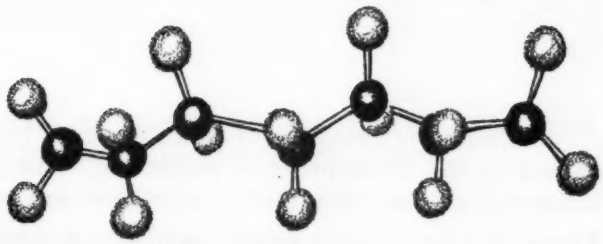
The problem of locating a fast moving object in the sky while aboard a 600 mph aircraft is solved by the use of a digital computer and the optical tracker. The airborne computer is fed the basic information regarding the position of the aircraft, the missile launch time, and predicted trajectory of the missile. The computer takes over control of the aircraft and optical system, and directs the optical tracker to search the proper segment of the sky. As soon as the target is acquired, the measurements begin. The tracker locks onto the target and continues to control the aircraft and the line of sight of the optical system.

The characteristic radiation of the missile during reentry is the result of reactions of the nose cone with the atmosphere. Radiations will vary depending on the configuration and composition of the nose cone--and on the angle of entry and attack of the missile.

Robert Toolin and Captain Thomas F. Conley of AFCRL were project and assistant project directors, respectively.



THE ATOMIC NUMBER EFFECT *in polyatomic molecules*



LT. S. R. LAPAGLIA, USAF
Chemistry Laboratory (ARL)

A knowledge of the nature and behavior of the excited states of polyatomic molecules is extremely important for the development of biophysics, biochemistry and chemistry in general. We consider in the following some work done at this laboratory which elucidates the nature of one of the two types of excited states found in all polyatomic molecules, the triplet state.

The electron has an internal degree of freedom which is represented as a spinning motion about its own axis. Taking this axis in the vertical direction, the direction of rotation may be ↑ or ↓. Or more succinctly, the two possible directions of rotation about a given axis are represented as ↑ and ↓. Let's assign to ↑ a spin + 1/2, and to ↓ a spin - 1/2. Taking the electrons two at a time, this arrangement of spins ↑↓ is called antiparallel, or a singlet, the net spin is + 1/2 - 1/2 = 0. While this arrangement of spins ↑↑ or ↓↓ is called parallel, or a triplet, the net spin is $\pm 1/2 \pm 1/2 = \pm 1$.

We have taken the electrons in pairs and developed this terminology for the following reasons. For the vast majority of stable organic and inorganic molecules in their ground electronic states (i.e., as found on the laboratory shelf) the electrons which compose these molecules exist together as pairs in the anti-parallel arrangement. For example the ground state of a 10 electron molecule is represented as

$$(\uparrow\downarrow)\ (\uparrow\downarrow)\ (\uparrow\downarrow)\ (\uparrow\downarrow)\ (\uparrow\downarrow)$$

Brackets are used to emphasize the pairing idea. Such a 10 electron molecule is water, H_2O or ammonia, NH_3. Each electron pair contributes + 1/2 - 1/2 = 0. to the net spin so the total spin is 0 and this is therefore a singlet state.

Under extreme conditions such as high temperature, chemical reaction or the absorption of radiation, enough energy may be put into the molecule so that this stable arrangement of electron pairs is broken up. These excitation processes result in excited states. Usually only one pair of electrons is separated, but even this results in two possible excited states,

I $(\uparrow\downarrow)$-----$(\uparrow\downarrow) \longrightarrow$ $(\uparrow\downarrow)$----$(\uparrow)(\downarrow)$

ground singlet state excited singlet state

this is called a singlet-singlet transition because the excited state still has zero total spin. The dots represent any number of electron pairs with antiparallel spins, so these statements apply to molecules with any number of electrons. The other possible excited state which can result from the break up of an electron pair, is the excited triplet state,

II $(\uparrow\downarrow)$----$(\uparrow\downarrow) \longrightarrow$ $(\uparrow\downarrow)$----$(\uparrow)(\uparrow)$

ground singlet state excited triplet state

The transition is called a single-triplet transition because the excited state is a triplet state, that is, it has a total spin of unity.

The single-triplet transition requires one of the electrons to flip over its spin in the excitation process. Since this is a rather improbable occurrence the singlet-triplet transition is also improbable. However, in the last twenty years evidence has accumulated which indicates that the triplet state is a very important participant in chemical processes, even in living systems. To study the singlet-triplet transition in polyatomic molecules one would like to have some kind of probe to put inside the molecule in order to induce these electron spin flips. This can be done quite easily by making use of a relativistic effect long known for atoms. The spin flips can be brought about through spin-orbit coupling. All we need know about spin-orbit coupling is that it is greatest in atoms of high nuclear charge (i.e., high atomic number), those near the bottom of the chemists periodic table. We expect spin flips, and therefore singlet-triplet transitions, to be more probable in atoms of high atomic number. For the study of molecules we want to incorporate the atom of high atomic

number directly into the molecule so that its nuclear charge will act as the probe which induces spin flips of the molecular electrons.

The increased probability of singlet-triplet transitions in atoms of high atomic number is called the atomic number effect, and it has long been observed for atoms. For molecules, this program of research has actually been carried out for two series of molecules. McClure (1) for the halogen benzenes and napthalenes, and the present author (2, 3) for the tetraphenyls of group IV atoms. In the latter case molecules of the following form were studied:

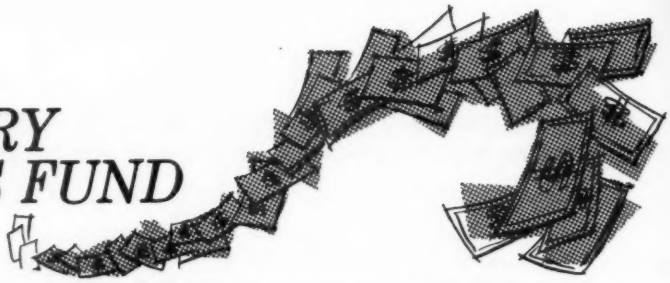
where X is any of the following atoms of ever increasing atomic number: carbon, silicon, germanium, tin or lead. It's evident that atom X acts as an atomic probe which will affect the electrons of all four benzene rings. As was to be expected, if the theoretical exposition is correct and the transition correctly identified, the singlet-singlet transition probability remained constant in going from X = carbon (atomic number 6) to X = lead (atomic number 82), but the singlet-triplet transition probability increased radically. Indeed, the singlet-triplet transition reported (3) in X = lead, is the most intense singlet-triplet transition ever seen in an organic molecule. Also, the singlet-triplet transition probability increased smoothly with the increasing atomic number of X. Experiments of this kind, and magnetic studies, serve to establish the triplet state as one of the two fundamental types of excited states of polyatomic molecules.

(1) McClure, Blake and Hanst, J. Chem. Phys. 22, 255 (1954).

(2) LaPaglia, J. Mol. Spectr. 7, 427 (1961).

(3) LaPaglia, Spectrochim. Acta 18, 1295 (1962).

LABORATORY DIRECTOR'S FUND



Under a new Air Force research funding policy, AFCRL has been allocated a budget of more than two million dollars to be spent entirely at the discretion of its Director.

"This special fund was created in response to the need for greater flexibility in the planning of research programs and the expenditure of research funds," Brigadier General B.G. Holzman, AFCRL Commander, said. The fund will permit scientists to develop a research program and implement it quickly, without the necessity of obtaining prior approval from higher headquarters.

This discretionary fund has been sought for a number of years by working Air Force Scientists as a means for giving the scientist greater responsibility and authority in planning and conducting his research program. The concept was endorsed as a managerial improvement in the recent Bell Committee Report to President Kennedy, in response to his request for a review of the management of research and development programs of government laboratories.

A total of ten million dollars was allocated to various Air Force laboratories. From this, the AFCRL was allocated more than two million dollars.

From among 29 proposals by AFCRL scientists, for funding under the special budget, 15 projects of exceptional merit from the standpoint of Air Force interest and scientific significance were funded from AFCRL's allocation. These are:

(1)The study of the neutral particle composition of the upper atmosphere by Hans E. Hinteregger will be aided by the purchase of a laboratory monochromator.

(2)The installation of a servo-drive system for the 150 foot parabolic antenna soon to be in operation at AFCRL's field site in Hamilton, Massachusetts for research in radio astronomy and space probe studies.

(3)Theoretical and experimental investigations by Marvin White bearing on the determination of interplanetary climatic conditions.

(4) The installation of a modified pulse doppler radar in high flying aircraft will serve David Atlas in measurements of the field of vertical motion in severe convective storms.

(5) Measurements and mapping of infrared celestial background radiation as a function of wavelength and celestial coordinates, a program to be conducted by Russell G. Walker.

(6) Infrared research related to the Air Force's ballistic missile defense capability, to be conducted by Alva T. Stair.

(7) Construction of a 30 foot diameter precision parabolic reflector antenna as a millimeter wave research tool under a program conducted by Edward J. Martin.

(8) A program for obtaining observations of solar corpuscular radiation trapped in the near-earth space by the use of special satellites, to be conducted by Ludwig Katz.

(9) Basic research leading to the location and extraction of water from lunar and planetary surface materials, to be undertaken by John W. Salisbury.

(10) Instrumentation, by Wolfgang Pfister, of satellites to be used for measuring the particular densities and energy distribution of ions and electrons in specific regions of the outer ionosphere.

(11) Feasibility studies leading to the construction of techniques of an extremely large multiple plate antenna facility, to be undertaken by Alan C. Schell.

(12) The design and development of a scientific problem-oriented general purpose programming language symbol processor, by Floyd H. Cook.

(13) Use, by Ernst Czerlinsky, of a Mossbauer effects apparatus purchased by this fund, in the study of the properties of crystals.

(14) Theoretical work involving coherent electromagnetic and collective motion interaction with plasma, to be conducted under the direction of Lawrence C. Mansur.

(15) Investigations concerning optical properties of matter, from a crystalline viewpoint, to be directed by Johannes N. Plendl.

MHD applications / power generation

KENNETH R. CRAMER, Thermo-Mechanics Research Laboratory (ARL)

Magnetohydrodynamics, the new-old applied science, embodies the principles of electrodynamics and aerodynamics and attempts to predict the behavior of the flow of electrically conducting fluids through magnetic fields. The first magnetohydrodynamic investigations were conducted by Faraday who reported in 1831 his attempts to measure the voltage induced in the Thames River by its motion through the earth's magnetic field and experiments with the flow of mercury between the poles of a magnet. He also proposed the use of tidal flows through the earth's magnetic field for power generation. The first practical application was a direct current electromagnetic mercury pump that was conceived by Hartman in 1918. Relatively few investigations were undertaken until the last decade when research activity increased considerably because high temperature, electrically conducting gases became important in engineering technology.

The existence of magnetohydrodynamic phenomena provides a large new field of research as well as a technological reservoir for practical applications and inventions. To date, application of the MHD produced motor force has been investigated as a method for creating drag and reducing the surface heat transfer of very high speed aerodynamic bodies. By proper orientation of this force, conducting fluids can also be pumped, accelerated, or utilized as a propulsion device. High temperature gases may be compressed with magnetic fields or restrained from coming in contact with confining surfaces. The self-pinching capability of highly ionized gas flows is being investigated as a means of confining deuterium or deuterium and tritium ions to produce controlled fusion.

While many other magnetohydrodynamic devices are being invented and will be invented, the generation of power by MHD devices is presently the most promising and economically important. For example, by 1982 it has been estimated that 400 million kw of additional power, approximately twice the existing capability, will be required in

the United States. Modern steam turbine generation plants operate at cycle efficiencies of 40%; whereas, the anticipated MHD systems efficiencies will be between 55 and 60%.

Generation of MHD dc power can be accomplished by replacing the solid conductors of mechanical generators which move through a magnetic field by a flowing, conducting fluid. AC power can be produced with inverters or time dependent generators. Two dc generators have been proposed, the Faraday generator and the Hall generator. The Faraday generator is the MHD version of the mechanical generator; whereas, the Hall generator produces power from flowing, low density gases and is designed to produce and utilize large Hall currents. In both generators the conducting medium is forced across a magnetic field and between electrodes connected to an external load thereby creating an emf and a resulting current which is proportional to the product of the velocity and the magnetic field strength. The power generated per unit volume is the product of the potential difference and the transverse component of the current.

Since the generator extracts electrical power from the kinetic energy of the fluid and the production of this energy is best accomplished thermally, the most suitable working fluids are gases. Because a high temperature gas is compressible and has a non-negligible viscosity and electrical resistance, the generator must be carefully designed to produce the power efficiently.

The important electrical and aerodynamic design parameters and losses that must be selected or minimized to obtain optimum generator performance are: (1) Electrical - gas conductivity, magnetic field strength, magnet power, Hall current losses, Joule heating losses, end power losses; (2) Aerodynamic - channel area distribution, channel length, gas velocity, friction losses, heat transfer losses, and pressure losses.

The prime electrical requirement is that the conductivity of the gas be sufficient to produce the required power with practical magnetic field strengths. This requirement can be satisfied by ionization of the parent gas or by seeding the gas with a more easily ionized material. Conductivities of the required order, i.e., 10^2 to 10^3 mhos/meter, can be produced at modest pressures and at temperatures between 4,000°F to 5,000°F. These gas pressures and temperatures correspond with those required for the cycle's thermal efficiency to exceed the efficiencies of modern steam turbine power plants. Since minimum gas temperatures will be about 4,000°F to prevent loss of conductivity, the

exhaust gases will remain at very high temperatures. This residual heat must be used effectively in the cycle to preheat the gas and to operate a standard steam turbine generator.

With these gas conductivities, magnetic field strengths required to produce 500 megawatts, an estimated minimum future station capacity, will be 20,000 to 30,000 gauss which can be produced with water cooled electromagnets requiring approximately 8% of the generated power. This power consumption can be eliminated with cryogenically cooled super-conducting magnets constructed of niobium-tin and field strengths of 100,000 gauss or greater are possible. However, large magnetic field strengths may produce Hall currents which can be eliminated with segmented electrodes.

Joule or ohmic heating losses are produced by the electrical resistance of the fluid and can be reduced by lengthening the generator channel to reduce the current density. This lengthening increases the friction losses through the channel.

Power can be lost at the generator ends via the reverse currents permitted by termination of the magnetic field since the electrodes are at a high potential difference with each other. These losses, which can be as much as 1/3 of the generated power, can be eliminated by extending the magnetic field beyond the generator, but this increases the pressure drop through the channel. An exponentially decreasing extension minimizes the end pressure and power losses for a given channel length and height. The remaining losses can be reduced to a few percent by increasing the channel length to height ratio which reduces the influence of the channel ends.

Friction and heat transfer losses increase as the generator length increases. Heat transfer losses can be reduced using insulating materials and high temperature electrodes to reduce electrode cooling.

Channel area distribution can be selected to produce a constant temperature, constant pressure, constant density or a constant velocity flow. Distributions have been investigated to determine which produces the maximum power with minimum losses. Constant velocity flow closely approximates the optimum generator design, but requires a gradually increasing area. The simplest construction is a constant area channel in which the pressure and temperature drops.

The flow velocity must be carefully selected; although the power generated increases as the flow velocity is increased, the gas temperature decreases which in turn lowers the conductivity. The

optimum subsonic velocity has been calculated to be 80% of the speed of sound in the gas.

It appears that a proper design will eliminate the Hall current losses and minimize the heat transfer and end losses. Since the generated power and the friction losses increase while the Joule heating losses decrease with length, an optimum length can be determined in terms of an efficiency that is a function of the length. The generator efficiency is defined as the ratio of the actual power generated to the ideal power generated. Efficiencies of 80% are possible. The performance characteristics of the generator are important for efficient operation of a power station. The power of a Faraday generator first increases and then decreases as the external load increases since the voltage difference across the generator increases while the generated current decreases. These generators can be operated at their maximum power by distributing peak loads to mechanical generators operating in the same system (which are required anyway to effectively use the high temperature exhaust gases to obtain high plant thermal efficiences). Plants of this type are expected to operate at thermal efficiencies between 55 and 60%.

Experimental investigations are being conducted and several MHD generators have been operated for short time periods with power outputs up to 600 kw using combustion products of JP4 fuel and oxygen seeded with one percent potassium. Generator performance has not equalled theoretical predictions due to energy losses, Hall current losses, etc. However, these experiments are in their early phases and considerable progress is anticipated.

Significant advances are necessary in several areas if MHD plants are to become economical. Progress is required to produce low cost high temperature materials, substantial increases in the conductivity at lower temperatures, and elimination of costly inverters. A considerable number of investigations having these goals are being conducted and many schemes for producing ac power have been proposed which employ periodic variation of the magnetic field, the flow, or the conductivity.

In conclusion, MHD power generation has a very promising future and will probably become a reality in the next decade. In addition, many other practical MHD devices will also be invented as progress continues in this challenging area of technology.

* A condensation of an invited paper presented at the Southwestern Ohio Section of the American Nuclear Society, September 1962, at Battelle Memorial Institute at Columbus, Ohio.

NEW HORIZONS FOR WEATHER RADAR

Meteorological Research Laboratory (AFCRL)

Radar measurements of wind speeds to within an accuracy of less than one-half mile per hour have been obtained by Dr. Roger Lhermitte of AFCRL, as a result of a new spectrum analyzer recently placed in operation at AFCRL's Weather Radar Site in Sudbury, Massachusetts.

The new analyzer, together with Doppler weather radar techniques developed by Dr. Lhermitte permit the recording of wind speeds and directions with a much higher resolution in time and space than has heretofore been possible. Both vertical and horizontal wind components can be measured. At present, the spectrum analyzer permits observations only during rainy or snowy periods. It is believed that the ultimate development of the technique will permit wind measurements in clear weather.

The new frequency analyzer is designed for real-time Doppler frequency analysis and uses 100 magnetostrictive filters of 3 cps bandwidth, spaced 14.7 cps apart in a comb array. On AFCRL's C-band pulse Doppler radar this spacing is equivalent to increments of 0.4 meters per second in radial velocity. The rapid processing and display (on an oscilloscope) of the spectrum given by the frequency analyzer, combined with its high resolution of frequencies, make the equipment especially suitable for measuring the horizontal wind at all altitudes.

The measurement of wind speeds to within an accuracy of a half-mile per hour is much better than accuracy obtainable with conventional radar or radio balloon tracking methods. The pattern produced by the velocity output of the spectrum analyzer as the beam rotates also provides a measure of shear, or difference between the wind speed at the top and bottom of the radar beam, and of the amount of turbulence within the reflecting region.

Radars of greater power and sensitivity, together with the AFCRL radar data processing techniques, show promise of providing the meteorologist a tool for measuring winds in fair weather as well as foul with much greater accuracy. With order-of-magnitude improvements in transmitted power, receiver sensitivity, and

antenna gain, there is some hope that Doppler radars will also be able to detect clear air turbulence which is a serious hazard and discomfort to jet flight.

While it is still too early to predict the obsolescence of direct balloon-borne sampling methods that are now widely used in sounding the atmosphere, this is one of the objectives of AFCRL's Weather Radar Group.

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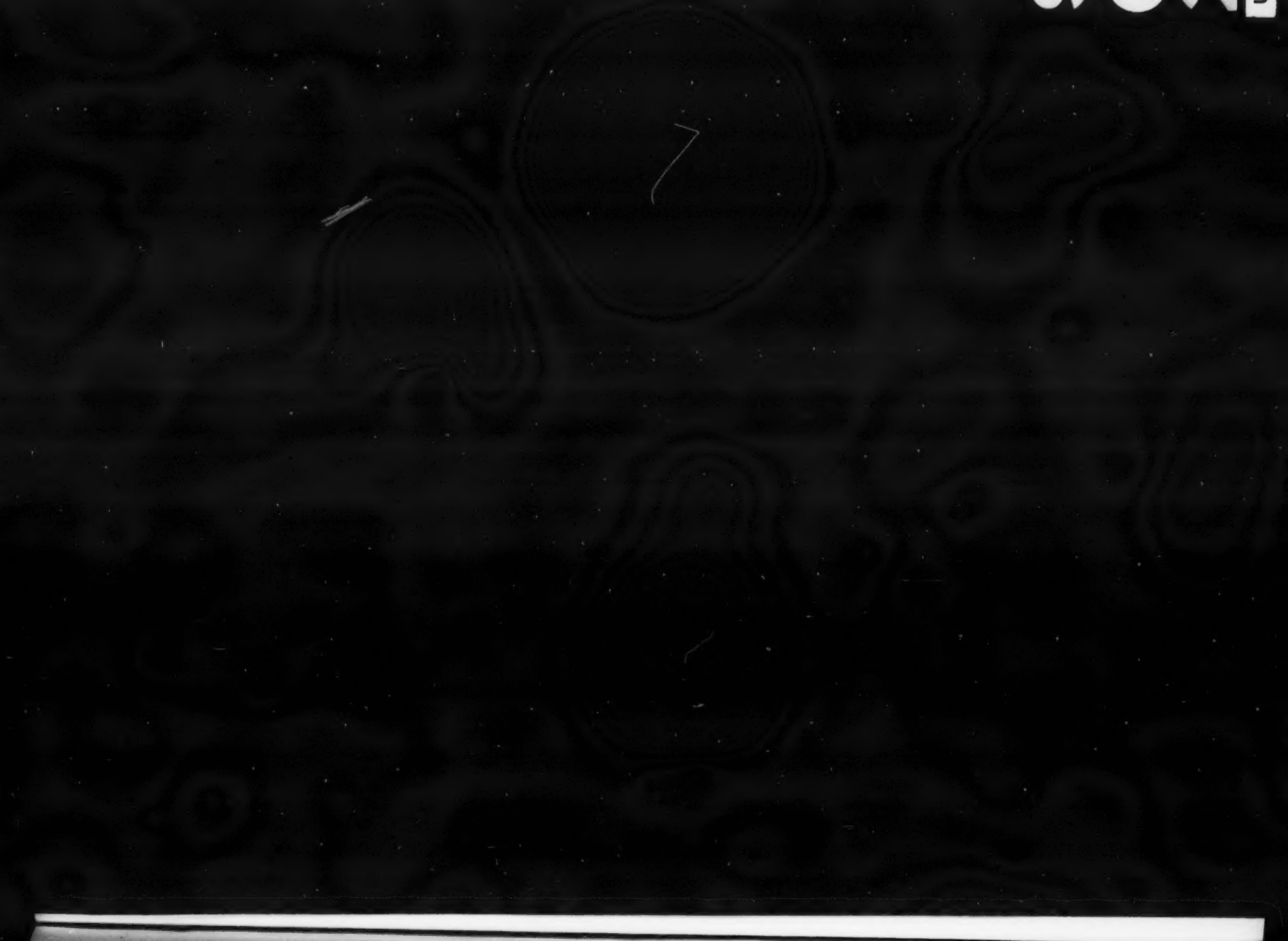
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